Economics of Ecosystem Change

Ecosystem-Based Decision Support Tools for Fisheries Management

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Why Should We Care?

"...in the long run, the economics of natural resources and the environment is as important to our well-being as the economics of money and banking. Our national economic future depends on the way we use our energy sources, renewable and non-renewable; on the way we use our subsurface minerals, our forest our soil resources, our ocean fisheries; on the quality and quantity of water we can make available for household use; and on the quality of the air and what we do with toxic wastes."

-Robert Solow

Major Use Values of Marine & Coastal Ecosystems

- Commercial Fishing
- Recreational Fishing
- Swimming
- Boating
- Tourism
- Aesthetics
- Others?

Don’t Forget About Non-Use Values

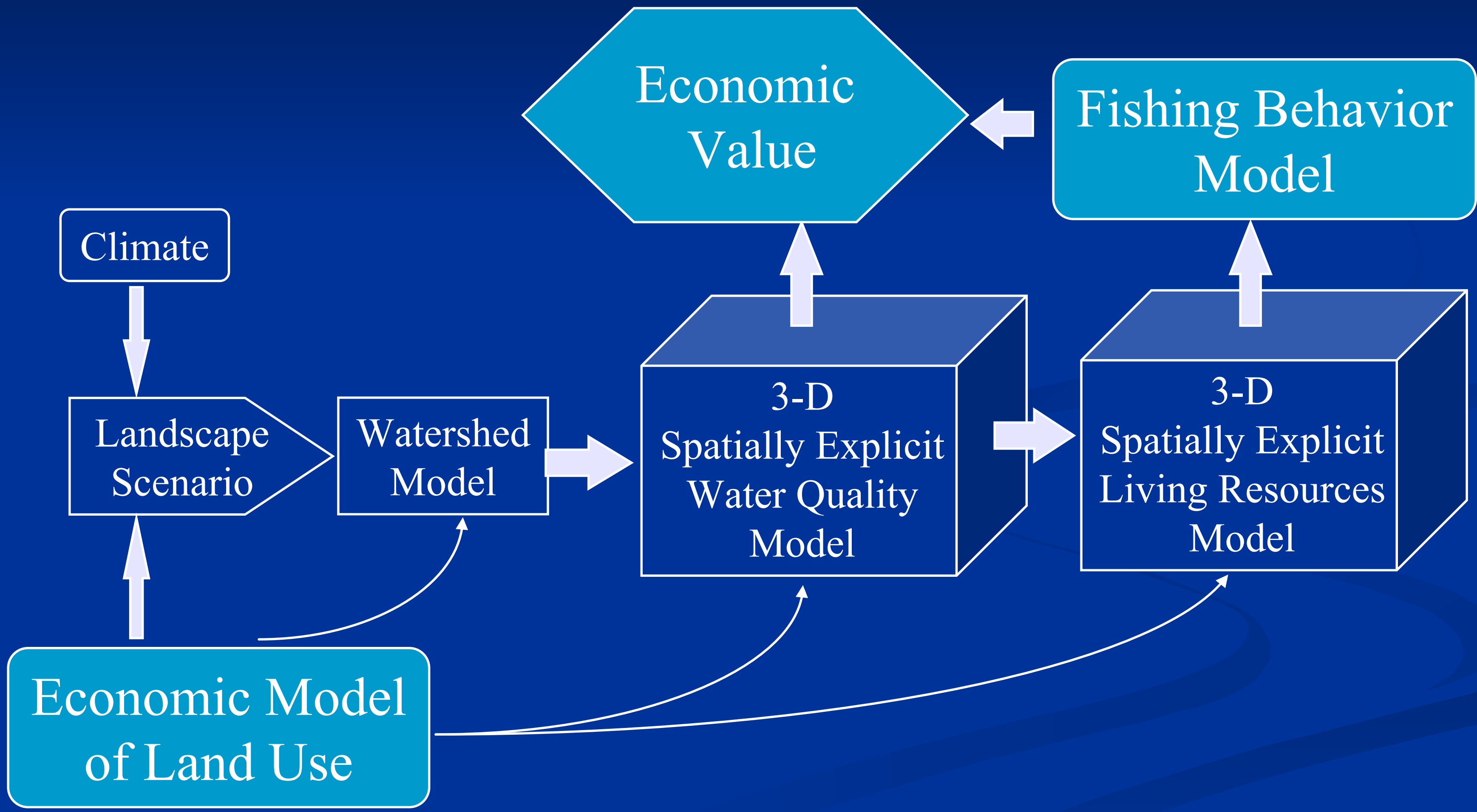
- Existence Value
  - Societies willingness-to-pay for “healthy” marine ecosystems over and above use
- Option Value
  - Preserving ecosystems for some potential future use. Deals with irreversibility and extinction issues.
- Bequest Value

These are challenging to measure well, usually requiring surveys of a public with little knowledge of what they are being asked to value

Economics – A Driver and a Metric

- Economics is a driver of change in coastal and marine ecosystems
- Economics is a metric of the consequences of change in coastal and marine ecosystems
- An integrated assessment explicitly incorporates economics as both the driver and the metric.

Economics & Coastal Ecosystems



Overview of 3 Studies

- Impacts of Dissolved Oxygen on:
  - Recreational fishing for striped bass in Chesapeake Bay
  - Commercial trotline fishery for blue crabs in Chesapeake Bay tributaries
  - Recreational fishing as an indicator of human use of impacts of eutrophication in northeast U.S. estuaries

Limitations

- Not multispecies
- Estuarine systems
- Environmental – impacts limited to effects of dissolved oxygen
- Statistical Approaches
- No Long-Term Dynamics

Ecosystem States & Recreational Fishing

Water Quality Change

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Expected Catch Rate Change

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Random Utility Model

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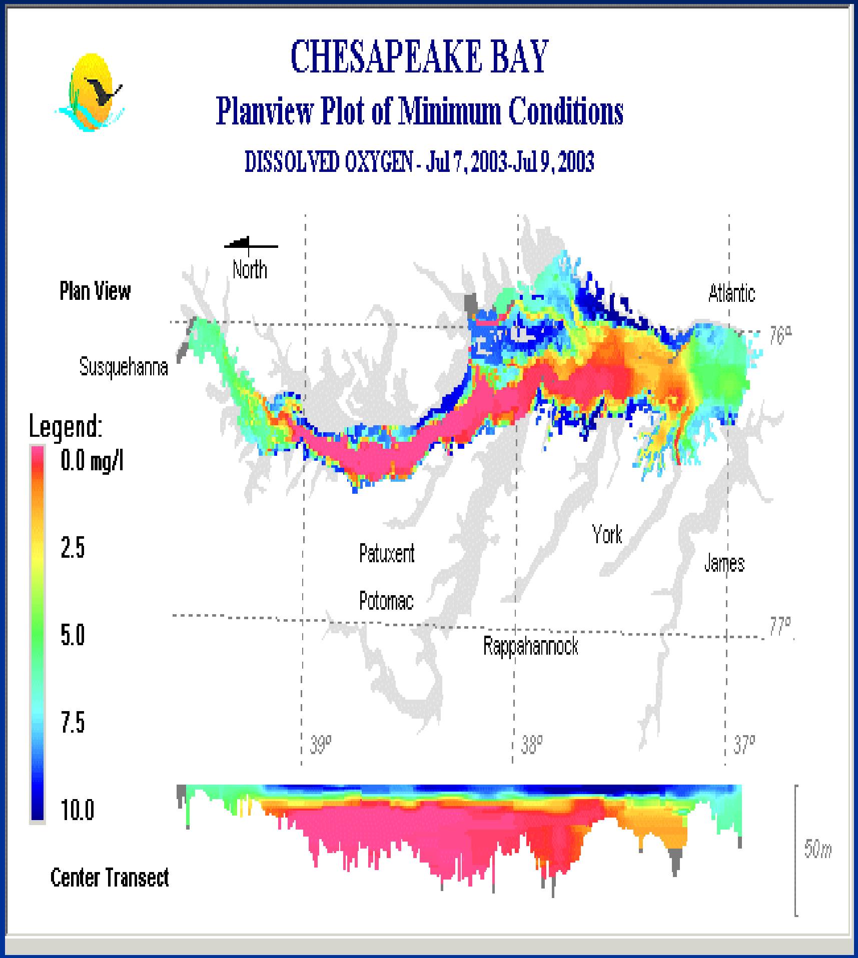
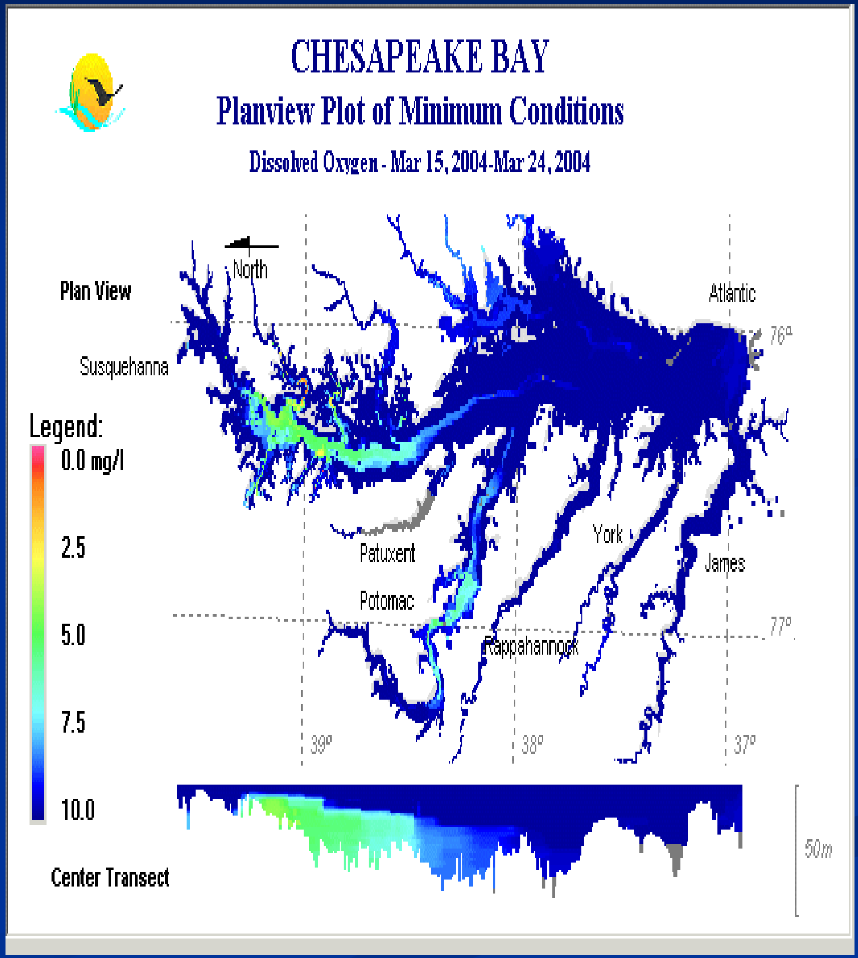
Benefit Change

Change in Ecosystem Condition: Chesapeake Bay

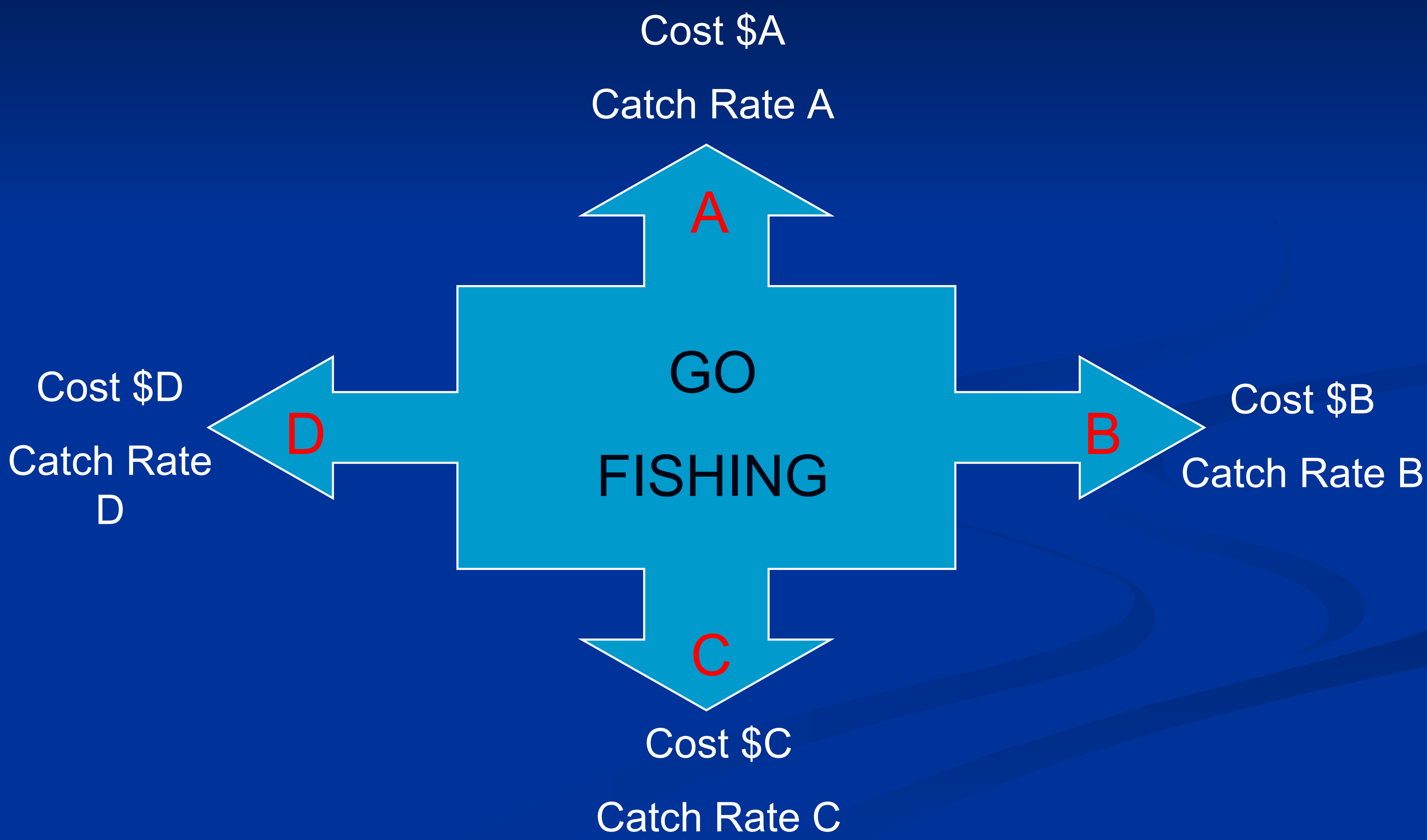




Expected Catch Rate is a Function of Ecosystem State

Variable	Coefficient	t-test
Constant	-5.897	-6.592*
Historic catch rate	0.631	11.396*
LN(Hours)	0.344	3.337*
Years Fished	0.019	6.073*
Days Fished (12)	0.001	1.474
Surface Temp	**-0.255**	**-2.596***
Bottom Temp	**0.323**	**2.838***
Surface Oxygen	**0.259**	**4.414***
Bottom Oxygen	**0.225**	**1.953***
Oxygen^2	**-0.017**	**-2.023***

Ecosystem Choices - Observed



Random Utility Model

- Each Fisherman Is Observed at 1 out of 407 Fishing Choices With Different Time/Travel Costs and Catch Rates. The probability of choosing any of these sites can be estimated:

Variable	Parameter Estimate	Chi-Square
TRAVEL COST	-0.0355	214.99
TRAVEL TIME	-0.8291	74.19
F(EXP CATCH RATE)	0.6520	7.50

Eliminate Sites – Value of Access to Those Sites

	Average Net Value per Trip	Number of Striped Bass Trips	Annual Value
Maryland	$62.22	505,199	$31,433,452
Virginia	$69.95	316,633	$22,148,495
Total*			$53,581,947

* Total is underestimate, since each state's access value assumes fishing is available in the other state.

What is the Cost of an Impaired Ecosystem? What is the Gain of Restoring Health to an Ecosystem?

Dissolved Oxygen	Change in Net Value Per Trip	Total
$\leq$5 mg/l	-$6.00	-$4,928,480
$\leq$4 mg/l	-$7.48	-$6,144,171
$\leq$3 mg/l	-$8.84	-$7,264,993

Asset Values From Striped Bass RUM – 3% Discount Rate

Total (Access Value) Current	$1.786 Billion
Increased Catch Rate	$135.7 Million
Lower Water Quality (DO)	
<= 5 mg/l	-$ 164.2 Million
<= 4 mg/l	-$ 204.8 Million
<= 3 mg/l	-$ 242.2 Million

Blue Crabs and the Environment

$$Y_i(t) = S_i(0)\, g_i(\theta_i)\left(1 - e^{-f_i(\mathbf{X}_i)t}\right)$$

Yi(t) = trotline harvest on *i*th fishing ground over period t

Si(0) = initial stock of crabs

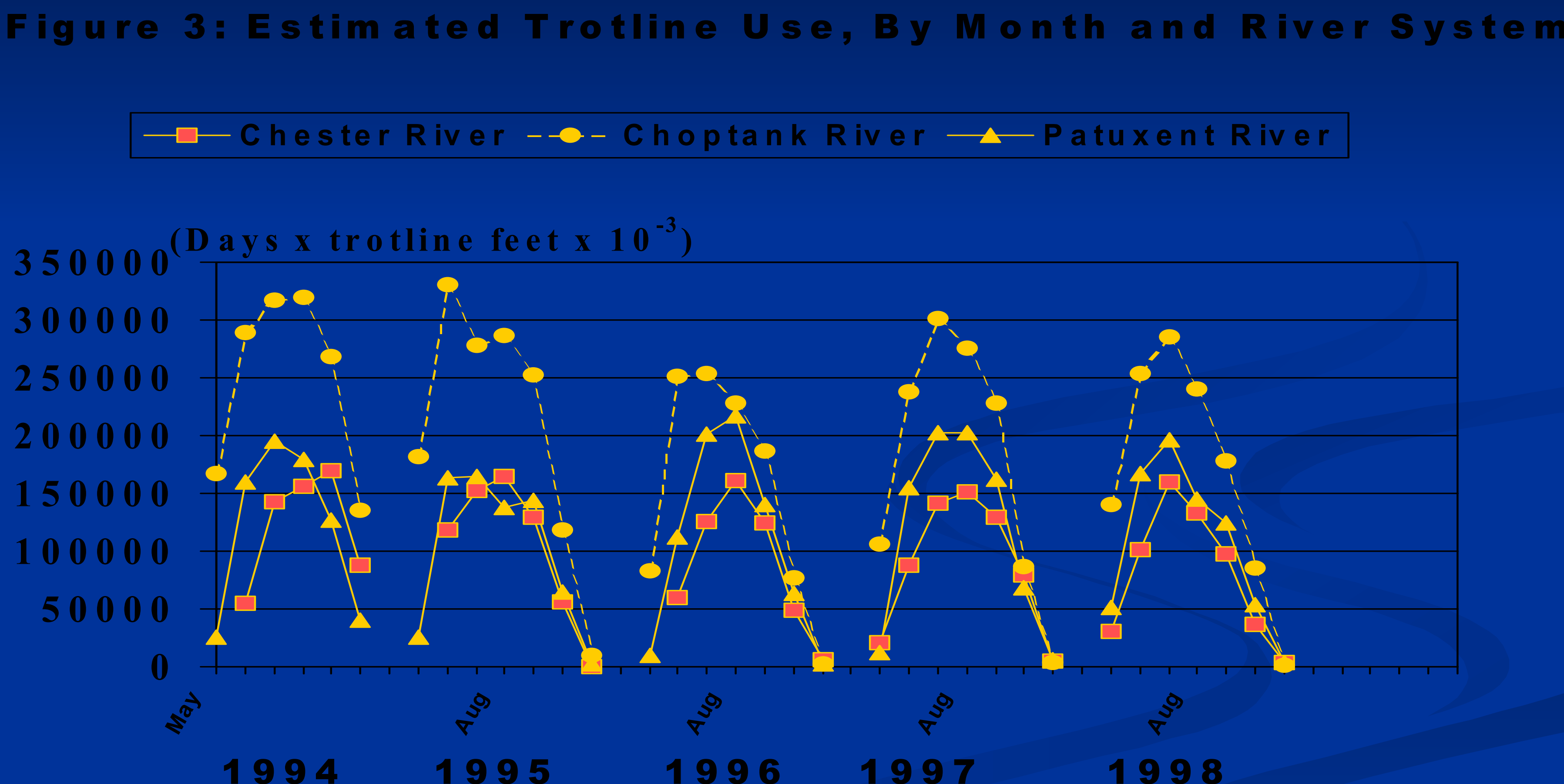
Xi = vector of inputs

θ_i = vector of environmental parameters

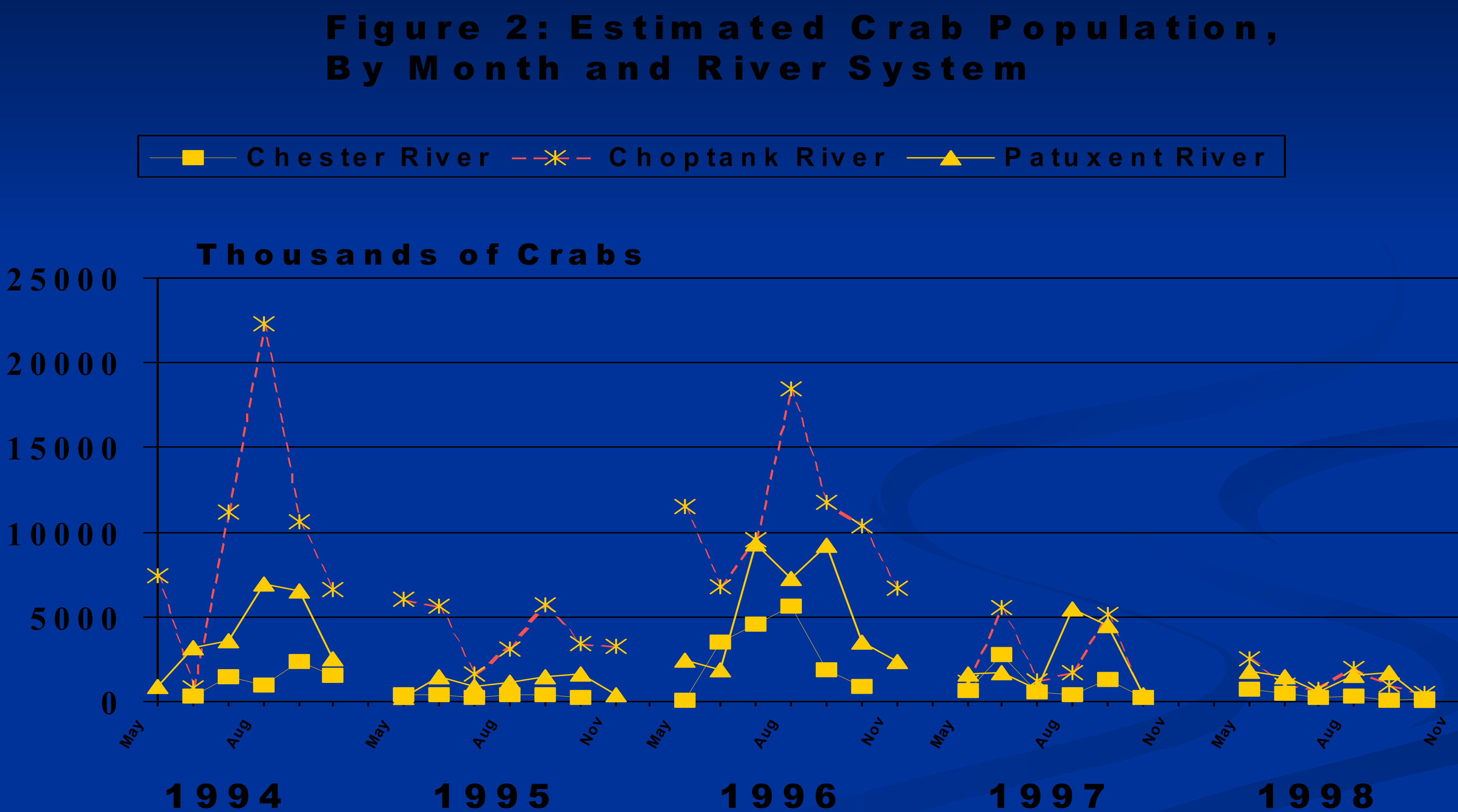
Threshold Statistical Yield Model

$$\frac{Y_{i,t}}{S(0)_{i,t}} = \begin{cases} \left(1 - e^{-g\theta_{i,t}}\right)\left(1 - e^{-qX_{i,t}}\right) + \varepsilon_{i,t} & \text{if } \theta_i \leq \overline{\theta}_i \\ \left(1 - e^{-qX_{i,t}}\right) + \varepsilon_{i,t} & \text{otherwise} \end{cases}$$

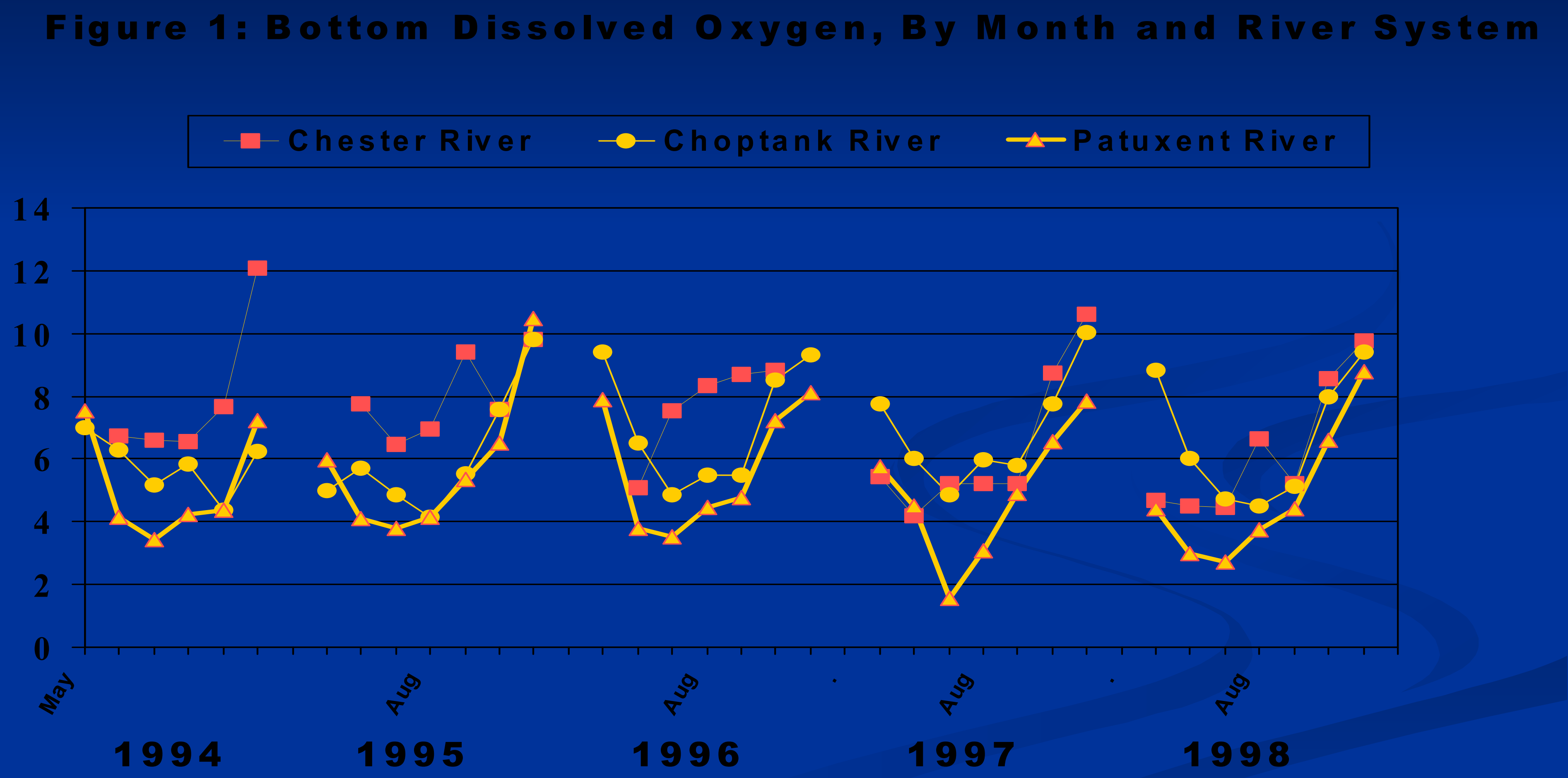
Fishing Effort



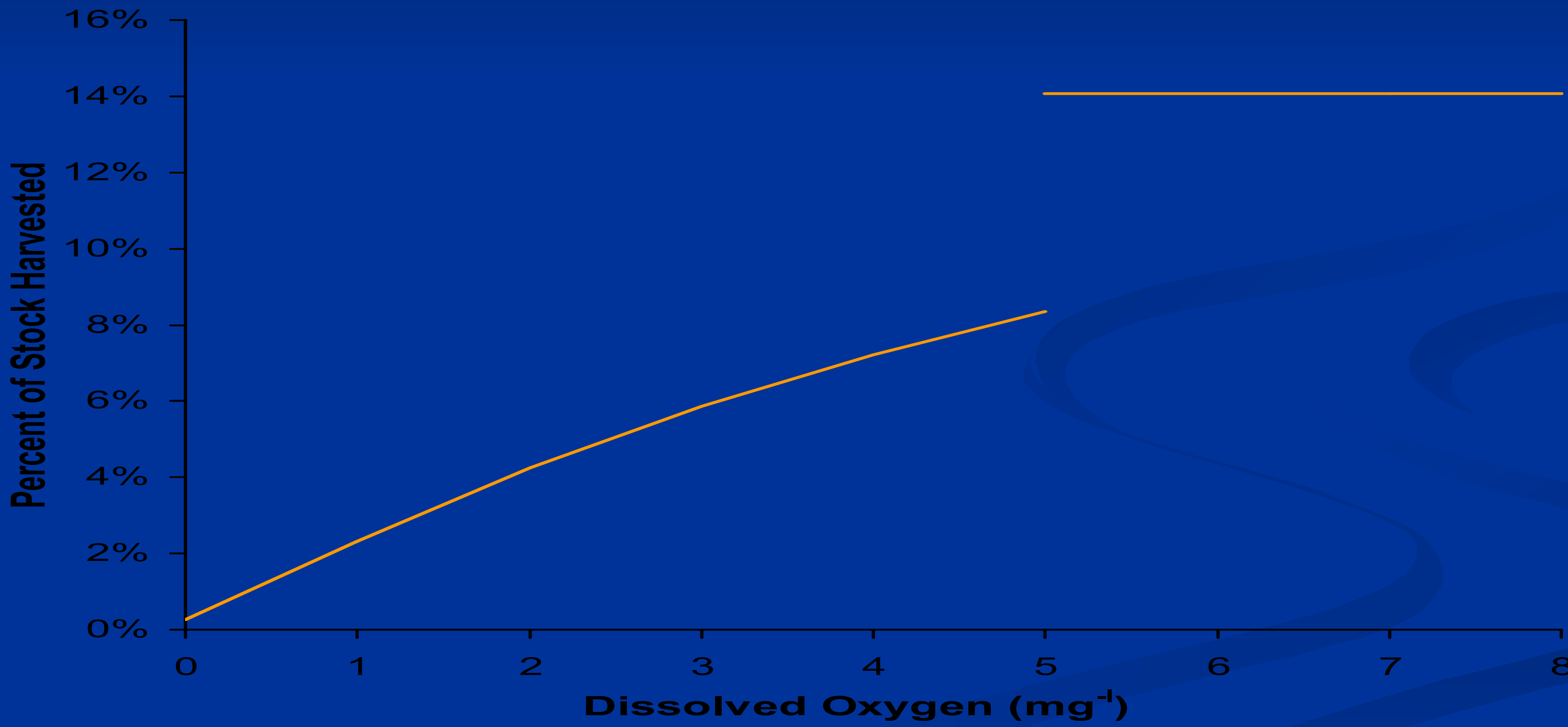
Crab Abundance



Dissolved Oxygen



DO Effect on Harvest

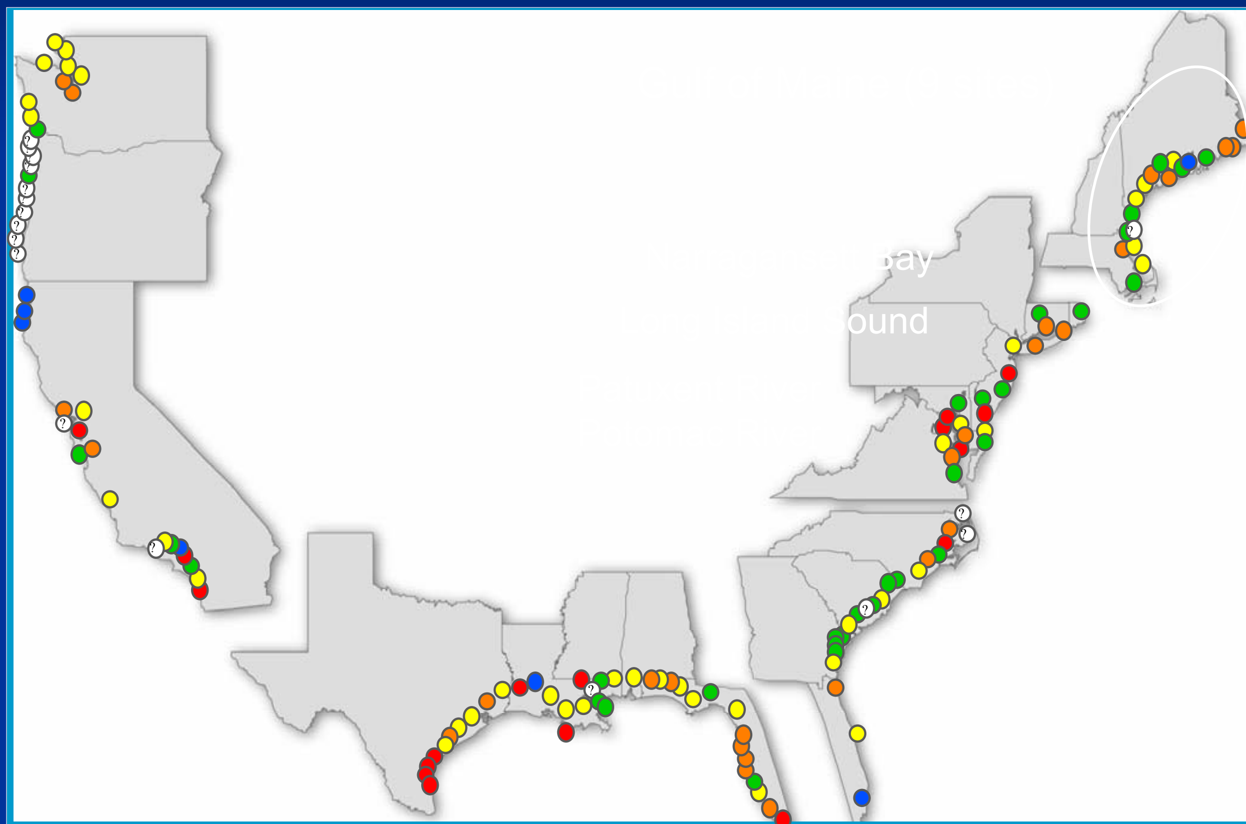


National Eutrophication Ecosystem Assessment Project

- National Centers for Coastal Ocean Science
  - Suzanne Bricker & Andrew Mason
- Develop Eutrophication Indicator
- Develop Human Use Indicator of Eutrophication

CICEET Funded Project

- Selection of 13 Mid Atlantic/Northeastern US estuarine systems to perform pilot project



Long Island Sound (2002) – NEEA/ASSETS Application

ASSETS: GOOD

Indices	Methods	Parameters	Value	Level of expression	Index
Overall Human Influence (OHI) ASSETS: 3	Susceptibility	Dilution potential	High	Moderate susceptibility	MODERATE
		Flushing potential	Low		
	Nutrient inputs	Moderate nutrient input			
ASSETS: 4	PSM[*1]	Chlorophyll *a*	0.5	Moderate	MODERATE LOW
		Epiphytes	No Data		
		Macroalgae	No Data		
	SSM[*2]	Dissolved Oxygen	0.25	Low	
		Submerged Aquatic Vegetation	SAV has increased	Low	
		Nuisance and Toxic Blooms	No Data		
ASSETS: 4	Future nutrient pressures	Future nutrient pressures decrease			IMPROVE LOW

[*1] – Primary symptoms method

[*2] – Secondary symptoms method

$$\sum_{i=1}^{n}\left(\frac{A_z}{A_t}\right)\left(\begin{matrix}Expression\\ value\end{matrix}\right) =$$ Symptom level of expression value for estuary

n – Total number of zones

Az – Area of zone

At – Total estuary area

Human Use Indicator

- How about recreational fishing?
  - Winter flounder
  - Bluefish
  - Striped Bass
- Used same modeling approach as CB striped bass, except
  - Aggregated water quality data to a single monthly average for each estuary

All Estuaries - All Fish Species

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	NS
Bottom Water DO^2	NS
Surface Chl a	NS
DO x Temp Cross Product	↑

All Estuaries – Individual Fish Species

Striped Bass

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	↑
Bottom Water DO^2	NS
Surface Chl a	↑
DO x Temp Cross Product	↑

All Estuaries – Individual Fish Species

Bluefish

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	NM
Bottom Water DO^2	NM
Surface Chl a	NM
DO x Temp Cross Product	NM

All Estuaries – Individual Fish Species

Winter Flounder

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	NM
Bottom Water DO^2	NM
Surface Chl a	NM
DO x Temp Cross Product	NM

Mid Atlantic Estuaries - All Fish Species

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	↑
Bottom Water DO^2	NS
Surface Chl a	↓
DO x Temp Cross Product	NS

Gulf of Maine Estuaries - All Fish Species

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	↓
Bottom Water DO^2	↓
Surface Chl a	↑
DO x Temp Cross Product	NS

Mid Atlantic Estuaries - Individual Fish Species

Striped Bass

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	NS
Bottom Water DO^2	↑
Surface Chl a	↓
DO x Temp Cross Product	↓

Gulf of Maine Estuaries - Individual Fish Species

Striped Bass

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	↓
Bottom Water DO^2	↓
Surface Chl a	↑
DO x Temp Cross Product	NS

Mid Atlantic Estuaries - Individual Fish Species

Bluefish

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DO x Temp Cross Product	NS

Gulf of Maine Estuaries - Individual Fish Species

Bluefish

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Bottom Water DO	NM
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Mid Atlantic Estuaries - Individual Fish Species

Winter Flounder

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	NS
Bottom Water DO^2	NS
Surface Chl a	↑
DO x Temp Cross Product	NS

Gulf of Maine Estuaries - Individual Fish Species

Winter Flounder

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	NM
Bottom Water DO^2	NM
Surface Chl a	NM
DO x Temp Cross Product	NM

Closed Estuaries - All Fish Species

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	↑
Bottom Water DO^2	NS
Surface Chl a	↓
DO x Temp Cross Product	NS

Closed Estuaries - Individual Fish Species

Striped Bass

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	↑
Bottom Water DO^2	↑
Surface Chl a	↓
DO x Temp Cross Product	↓

Closed Estuaries - Individual Fish Species

Bluefish

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	NS
Bottom Water DO^2	↑
Surface Chl a	NS
DO x Temp Cross Product	↓

Closed Estuaries - Individual Fish Species

Winter Flounder

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	NS
Bottom Water DO^2	NS
Surface Chl a	↓
DO x Temp Cross Product	NS

Open Estuaries - All Fish Species

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	↓
Bottom Water DO^2	↓
Surface Chl a	NS
DO x Temp Cross Product	NS

Open Estuaries - Individual Fish Species

Striped Bass

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	↓
Bottom Water DO^2	↓
Surface Chl a	↑
DO x Temp Cross Product	NS

Open Estuaries - Individual Fish Species

Bluefish

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	NM
Bottom Water DO^2	NM
Surface Chl a	NM
DO x Temp Cross Product	NM

Open Estuaries - Individual Fish Species

Winter Flounder

Increase in Core Variables	Change in Fish Catch Rate
Bottom Water DO	NM
Bottom Water DO^2	NM
Surface Chl a	NM
DO x Temp Cross Product	NM

Conclusions

- Examples are a fraction of the total benefits that must be measured
- Economic losses due to use impairments from eutrophication can be estimated with properly designed studies
- Requires coordinating use data with water quality data
  - Spatially
  - Temporally
- Monitoring data efforts should include coordinated use data